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Does the Environmental Gain of Switching to the Healthy New Nordic Diet Outweigh the Increased Consumer Cost?

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Abstract: The new Nordic diet (NND) was designed by gastronomic, nutritional and environmental specialists to be a palatable, healthy and sustainable diet containing 30%-40% less meat than the average Danish diet (ADD), ≥ 75% organics, and more locally grown wholegrain products, nuts, fruit and vegetables. In this study, the NND was based on economic modelling to represent a "realistic NND bought by Danish consumers". The objective was to investigate whether the ADD-to-NND diet-shift has environmental consequences that outweigh the increased consumer cost of the diet-shift. The diet-shift reduced the three most important environmental impacts by 16%-22%, mainly caused by reduced meat content. The surcharge to consumers of the ADD-to-NND diet-shift was €216/capita/year. In monetary terms, the savings related to the environmental impact of the diet-shift were €151/capita/year. 70% of the increased consumer cost of the ADD-to-NND diet-shift was countered by the reduced socioeconomic advantage associated with the reduced environmental impact of the NND.

Key words: Environmental impact, health, life cycle assessment, meat, new Nordic diet, OPUS, organics, socioeconomic cost.

1. Introduction

On a global scale, agricultural production consumes large amounts of resources and releases large amounts of greenhouse gases (7.3-12.7 × 10^9 ton CO_2-eq, or 14%-24% of total global emissions [1], air pollutants, nutrients and pesticides). In 2011, Danish agriculture contributed with 0.01 × 10^9 ton, or 17% of the total Danish greenhouse gas emission [2]. Agricultural production alters soil structure and carbon storage in the soil, contributes to eutrophication, diminishes biodiversity, and causes unintended toxic effects on flora and fauna, including humans. Whereas, the growing and production of feed, food and beverages have serious impacts on the environment, we all have to eat and drink. But what we choose to eat and drink greatly affects the environmental impact on ecosystems, human well-being and resource expenditure. Our choice of diet is our own decision, although it is often associated with ethnicity, social status, habit, age and sex, and is influenced by policy and economics [3].

Production of livestock and dairy products typically cause greater environmental impacts than the production of cereal, fruit, vegetables and legumes [4-7]. Reducing the content of animal produce, particularly meat, and increasing the content of grain products, fruit and vegetables in the typical western diet would decrease the environmental impact of eating and drinking [8].

This study is part of the Danish multidisciplinary OPUS [1] project that develops, tests and aims at disseminating a new Nordic diet (NND). The NND was designed by gastronomic, nutritional and environmental specialists to be a palatable, healthy

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[1] Optimal well-being, development and health for Danish children through a healthy new Nordic diet.

and sustainable diet of Nordic origin containing 35% less meat than the average Danish diet (ADD), more fish, wholegrain products, nuts, fruit, berries and vegetables, locally grown food in season, and more than 75% organic produce [9, 10].

The impact of an ADD-to-NND diet-shift on climate change [6] and on a wider range of environmental impact [7] has already been investigated according to diet composition, transportation and production method (conventional vs. organic). The first of these studies was based on the OPUS dietary recommendations [9], while the second was based on 180 OPUS recipes for the NND.

In the present paper, we apply an economic model to fulfill the above-mentioned NND dietary recommendations in the most incentive-compatible way, i.e., composing the most realistic NND extrapolated to be bought by Danish consumers. Due to the higher level aggregation of food products in this study compared with previous studies, it was not possible to include impacts of transportation and production method.

The objectives of this study were first of all to investigate the environmental consequences of an ADD-to-NND diet-shift in "real life" as compared to previous studies which were only based on the NND-recommendations [6, 9, 10] and recipes [7], and secondly to find out if the expected socioeconomic value of the reducing impact associated with the diet-shift outweighs the increased consumer cost of the diet-shift.

2. Materials and Methods

The ADD is the reported Danish consumption of foods and beverages in 2010, drawing on data from the Danish consumer household survey [11] that displays the composition of the food and beverage budget on classification of individual consumption according to purpose commodity categories (COICOP) [12]. These budget components are converted to physical quantities using consumer price data estimated on the basis of household purchase data from a commercial market survey company (GfK).

The composition of the NDD is estimated by adjusting the items in the ADD by means of an economic simulation model developed for the purpose, which describes the consumers' preferences, such as preference-based substitutability between different food and beverage commodities. For example, if two commodities are close substitutes, an increased price of one of these products would induce a relatively strong shift in the consumption of these two commodities; the consumption of the commodity with increased price will decrease, and the consumption of the other product will increase. In contrast, if a commodity is not very substitutable with other products, the consumption of this product will only be affected to a limited extent. Hence, sensitivity to price changes (measured by price elasticities) reflects commodity substitutability. Because substitutability between food and beverage commodities, both with regard to nutritional value and with regard to their appeal to consumers' preferences varies significantly, the adjustments in the consumption patterns will also vary accordingly. Price elasticities were estimated econometrically on the basis of the above-mentioned commercial data from GfK for five household income classes.

Compared with the ADD, the NND involves a number of restrictions, including lower bounds for the intake of some products (categories of fruit, vegetables, seafood and whole-grains) and upper bounds for others (meat, sugar, saturated fat). These restrictions are implemented in the economic model by calculating the set of (implicit) prices that would be consistent with the restricted diet in a utility-maximizing equilibrium. In addition to ensuring compliance with the NND requirements, the implicit prices therefore also induce specific changes in the consumption of individual commodities, as a consequence of the above considerations about substitutability. Hence, the consumed quantities are

estimated by adjusting the ADD figures by means of implicit price changes and price elasticities, and these estimated quantities are multiplied by the original market prices in order to calculate the households' food budget in the NND.

The environmental impact of ADD and NND was compared using consequential life cycle assessment (LCA) [13] including the 15 impact categories [2] applied in the stepwise method [14] run in Simapro 8 software that facilitate monetization to evaluate the overall effect of the ADD-to-NND diet-shift in terms of environmental cost ("shadow price"). The consumer price of the diets was found in order to calculate the consumer cost of the diet-shift and relate this to the altered shadow price associated with the diet-shift.

Environmental impact data were taken from the international Ecoinvent [15] and the Danish LCA food [16] databases, supplemented by impact data from the literature, and all calculated according to the ISO standard 14040 [17]. The functional unit was one person year's diet measured in kg manufactured food and beverage products. The impact calculations covered all food and beverage produced for the diets, not only what was consumed, i.e., all waste from the farm gate to the table was included in the calculations.

The ADD was the reference to measure the environmental impact of NND. In this study, ADD was represented by 66 food and beverage products or categories supplied to the average Dane for private consumption, and further pooled into 53 categories to fit the available consequential LCA data. For the graphic representation in Figs. 1-3, all foods and beverages were further pooled into only 11 categories to ensure a lucid presentation.

[2] Carcinogenic and non-carcinogenic toxicity, respiratory inorganics, ionizing radiation, ozone layer depletion, aquatic and terrestrial ecotoxicity, nature occupation, global warming, acidification, aquatic and terrestrial eutrophication, respiratory organics, photochemical ozone effects on vegetation and non-renewable energy. For clarity, only data for the three most important categories (in terms of monetized impact) were presented in Figs. 1-2.

Substituting animal produce with vegetables, legumes, whole grain products and fruit may reduce the intake of protein and some essential nutrients. In this study, ADD and NND had similar energy and protein contents. This was obtained using the above-mentioned price elasticities for backward calculation of "implicit prices". These implicit prices represent the prices that would give the consumers the incentive to choose a diet with unchanged energy and protein contents, but with a dietary composition consistent with the NND specifications. But in addition to ensuring fulfillment of the NND-specifications, these implicit prices also determined the consumption of individual products within the commodity groups, which was the basis for the consequential LCA.

For effective and comprehensible presentation of the "real" potential of the ADD-to-NND diet-shift in reducing the environmental impact of diets, environmental impact of driving a Euro class 5 passenger vehicle [15] was used as a reference, that most consumers can relate to.

As a final twist, we tested one more diet in this study—a so-called "SensWell" modification of the ADD diet (SW-ADD). SensWell is a research project that develops and tests new healthy and satisfying foods and drinks that may come to substitute unhealthy foods and drinks in the daily diet through improving taste. In the SW-ADD, soft drinks are replaced with a theoretical designer drink with a high umami. Umami is the 5th faculty of taste (besides sweetness, sourness, saltiness and bitterness), and commonly found in its salt form as the food additive monosodium glutamate. For that reason, scientists consider umami to be distinct from saltiness. Umami is detected through specialized receptor cells which are present on the human and other animal tongues due to detection of the carboxylate anion of glutamate. Umami can be described as a pleasant "brothy" or "meaty" taste with a long lasting, mouthwatering and coating sensation over the tongue. 0.2 L of the designer

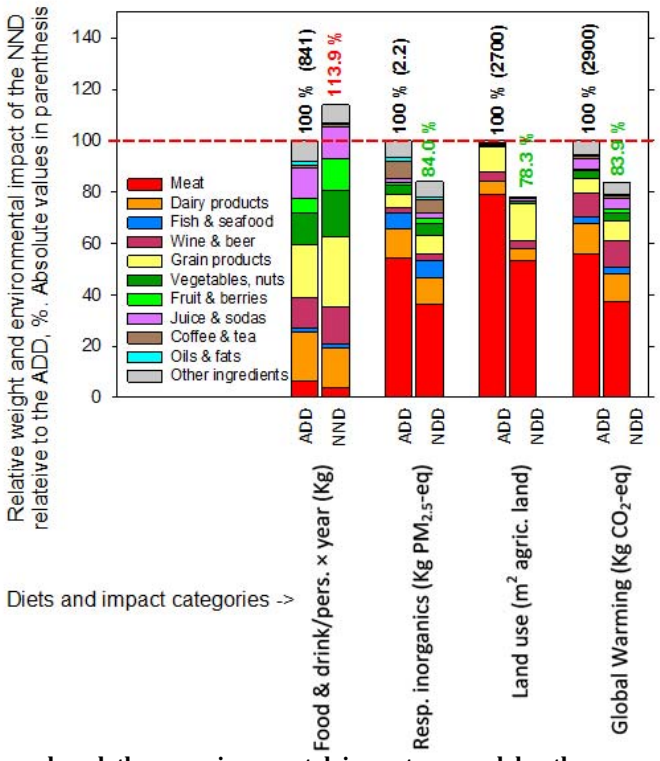

Fig. 1 The quantities consumed and three environmental impacts caused by the average Danish diet (ADD) and the modeled new Nordic diet (NND)—showing most important environmental benefits of the ADD-to-NND diet-shift.

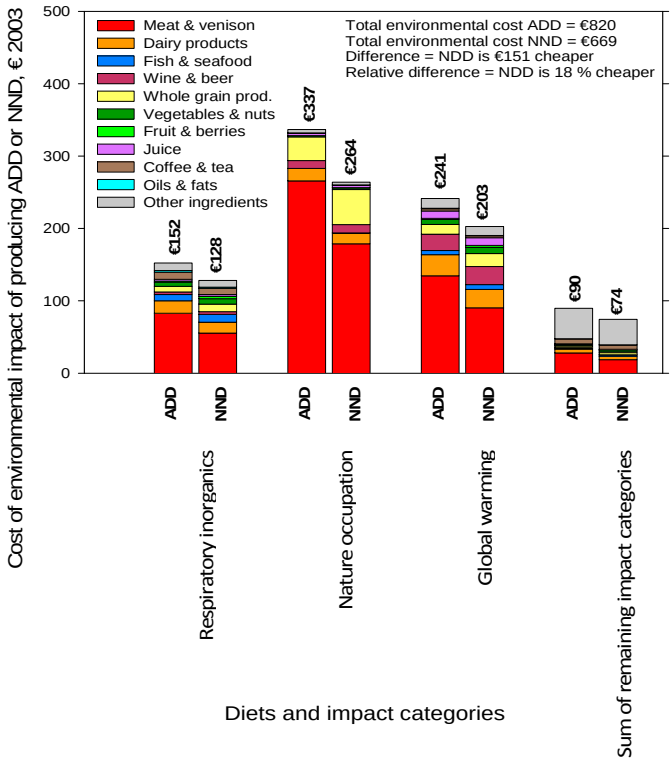

Fig. 2 The potential environmental cost to society (shadow price) of the average Danish diet (ADD) and the modeled new Nordic diet (NND) measured on the three most important impact categories and the sum of the remaining 12 categories.

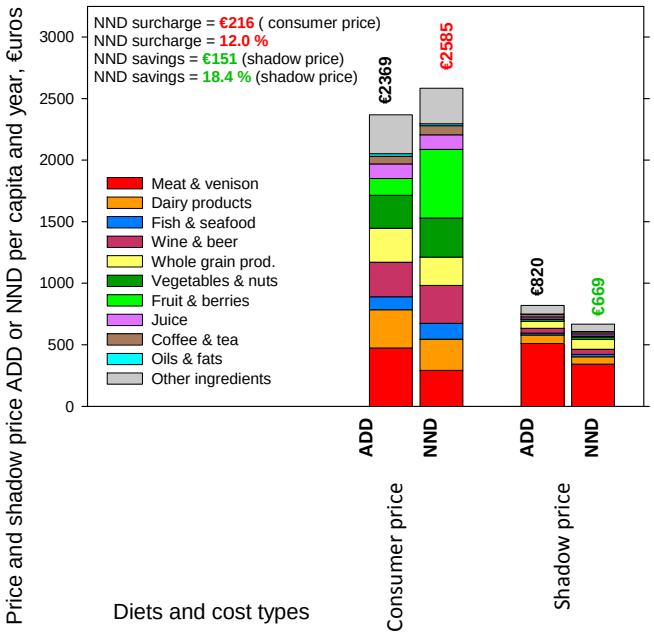

Fig. 3 Consumer price of the modeled average Danish diet (ADD) and new Nordic diet (NND) compared with the overall shadow price of the same two diets.

drink was assumed to be consumed by a third of the mature population every workday to replace soft drinks at "snack time". Our models show that it would not only replace a certain amount, i.e., about 15% of the total Danish consumption of soft drinks, but also other beverage and food, noticeably meat, e.g., beef and pork because of its high "umami content".

3. Results

The composition of the studied ADD and NND are given in Table 1. According to the NND dietary recommendations, tomatoes, cucumbers, coffee, tea, cocoa, wine, beer and spirits of non-Nordic origin should not be part of the NND since they are not of Nordic origin. However, in the present version of the NND, they are accepted at the level recommended in the Danish dietary guidelines based on the expectation that people will not do without these commodities in "real life". And as already stated, this paper aims at studying the Danish implementation of the NND in "real life". Table 1 shows that the modeled NND contains 39% less meat than the ADD, which are in accordance with the OPUS NND recommendations of a 30%-40% reduction.

The NND mass is 13.9% larger than that of the ADD mainly caused by a higher content of fruit and berries, vegetables and grain products. Fruit, berries and vegetables have higher water contents than most other commodities and their mass, together with grain products are genuinely larger in the NND (Fig. 1).

The NND reduced the environmental impact relative to the ADD measured by 12 of the 15 impact categories. The socioeconomically most important impacts (in terms of monetized impacts: respiratory inorganics, i.e., fine particles < 2.5 μm in aerodynamic diameter ($PM_{2.5}$), nature occupation and global warming) were all decreased by 16%-22%, mainly caused by the reduced meat content in the NND (Fig. 1). According to the Ecoinvent database [15] and the LCA food database [16], meat has a higher environmental impact per kg than most other commodities, and therefore dominates the environmental savings associated with the ADD-to-NND diet-shift.

Table 1 The mass and consumer price of each of the 53 food and beverage products or categories supplied to the Danish population in 2010 named the average Danish diet (ADD). The ADD is the reference to the modeled new Nordic diet (NND).

Ingredients	ADD kg/capita/year	ADD €/capita/year	NND kg/capita/year	NND €/capita/year
Apples	8.6	22.0	13.7	39.1
Bananas	7.4	19.0	11.6	30.1
Beef, veal	13.8	118.3	9.4	80.6
Beer	57.1	74.6	74.3	101.4
Berry fruits	2.1	32.7	16.7	319.9
Bread, sand cakes, cookies, biscuits, pasta products	58.4	207.5	42.9	141.4
Butter, butter containing spreads	4.4	29.0	0.0	0.0
Cabbage	7.5	13.4	10.7	18.3
Canned fruits, fruit salads	1.4	3.8	1.4	3.7
Cheese	13.8	109.3	12.5	102.1
Chocolate (dark, not filled)	4.9	61.0	4.6	59.1
Citrus fruits	10.5	20.7	39.1	116.9
Coffee, tea, cocoa	9.4	63.2	8.0	73.8
Dried fruit, nuts	2.7	39.7	2.7	39.7
Dried vegetables	0.5	2.1	0.5	2.1
Eggs	9.4	31.0	9.6	31.6
Flour, grains	105.8	58.2	179.1	77.0
Fresh and frozen fish	1.6	31.9	2.1	40.5
Fruit juice	22.9	34.0	22.8	34.3
Ice cream	20.6	37.7	16.9	31.0
Jam, honey, candy, raw marzipan, other sugar products	14.9	101.6	12.3	97.7
Lamb	0.91	13.2	0.9	12.8
Lettuce, Chinese cabbage, parsley	5.4	24.9	5.7	27.5
Margarine, all kinds	5.7	11.5	2.4	4.9
Mineral water, including soft drinks	79.7	80.5	82.1	81.9
Other fresh meat	0.3	2.7	0.3	2.7
Other fruits	4.1	16.0	3.0	12.0
Other milk products	8.1	32.5	8.0	32.2
Peaches, plums, cherries, avocados	8.9	17.1	13.6	27.6
Pears	1.4	5.9	1.9	8.7
Pizza, spring rolls, other cakes	6.6	35.8	4.3	25.6
Pork	11.0	88.9	6.3	50.9
Pork fat	0.3	0.6	0.3	0.6
Potato products	2.1	15.2	1.7	12.4
Potatoes	32.3	28.2	49.0	44.2
Poultry	9.2	66.5	3.6	26.2
Processed and mixed vegetables	13.1	38.0	9.3	26.8
Processed fish, fish products	8.3	50.1	10.2	60.7
Processed meat	3.5	23.3	3.5	23.2
Rice	7.9	10.4	8.0	10.5
Root crops, onions, mushrooms	24.6	43.8	54.2	77.2
Semi-skimmed, skimmed & buttermilk, infant formula	92.3	61.9	72.1	48.0
Shellfish (not canned)	1.1	10.8	1.5	15.3
Smoked and salted fish	0.6	12.4	0.6	13.4
Soup, sauce, bouillon, flavor products, yeast, preservatives	19.6	72.1	19.7	73.3
Soured whole milk, yoghurt	22.2	36.0	19.8	32.2

(Table 1 continued)

Ingredients	ADD kg/capita/year	ADD €/capita/year	NND kg/capita/year	NND €/capita/year
Sugar	3.5	8.9	0.7	1.9
Tomatoes, cucumbers, pepper bells, peas	18.1	62.1	19.7	69.6
Variety & cold meat, bacon, sausage	13.6	161.7	7.9	94.8
Vegetable juice	0.4	2.2	0.3	2.1
Vegetable oils	3.2	8.9	4.	11.5
Whole milk	11.3	10.3	8.1	7.3
Wine, port-, fruit- & dessert wine, champagne, spirits	44.5	206.3	44.5	206.6
Total	841	2,369	958	2,585
NND increase relative to the ADD	100%	100%	13.9 %	9.1 %

The absolute values of the environmental impact are given in Fig. 1, e.g., 2,900 kg CO_2-eq released per capita and year with the ADD, and 16.1% less for the NND (2,440 kg CO_2-eq). The CO_2-emissions associated with land use changes (LUC) were included in the global warming calculations as implemented by Ref. [7]. The inclusion of LUC (using values taken from Ref. [4]) more than doubled the difference between the global warming potential (GWP) of the ADD and the NND and nearly doubled the difference between the overall (monetized) environmental impacts of the two diets [7]. The content of meat and dairy products in both diets dominates in each of the three environmental impact categories.

The environmental cost to society (shadow price) of the ADD was found to be €820 and that of the NND €669 (Fig. 2). The ADD-to-NND diet-shift therefore potentially saves society for €151/capita/year in terms of improved environmental conditions. Fig. 2 shows that the meat content of both diets dominates the shadow price most through its impact on nature occupation and global warming and least through the sum of remaining impact categories. The second most important impact on nature occupation is grain products. The ingredients in the "sum of remaining impact categories" that dominate the environmental cost (shadow price) are sweets, coffee and cocoa. Fish and seafood have their highest relative impact on respiratory inorganics ($PM_{2.5}$; Figs. 1 and 2). This impact is caused by the considerable diesel consumption of fishing boats and the ice for onboard storage of the catch.

Fig. 3 compares the consumer price with the shadow price (potential environmental cost) of the two diets. The consumer price of the ADD was €2,369/capita/year and of the NND €2,585/capita/year when neither the price premium for organic production nor the savings by (mainly) having local produce in the NND were included (Fig. 3). The increase in consumer price associated with the ADD-to-NND diet-shift was €216/capita/year, or a 12% increase in consumer price, compared with ADD.

The potential savings (€151) reflected by the shadow price of the NND cover 70% of the increased consumer price (€216) for the NND. The environmental cost of driving a Euro class five car one mile was found to be €0.078/mile [15]. The savings caused by the diet-change (mainly caused by the lower meat content in the NND), equal the environmental impact of driving a Euro class 5 passenger car 1,935 miles/year, i.e., a quarter of the average annual mileage for a Danish passenger car.

Fig. 3 also shows that the shadow price of the meat content in both diets exceeds the consumer price. For the ADD the shadow price exceeds the consumer price by €35.78 or 8%. For the NND the shadow price exceeds the consumer price by €51.46 or 18%. Reducing the meat content in either diet is consequently the most effective way to lower the impact of diets seen in a socioeconomic perspective.

The SW-ADD increased the kg intake relative to the ADD by 0.8%, while the main impact categories were decreased by 1.9%-2.8% (data not shown). The consumer price for the SW-ADD increased by €96.54 or 4.1%, over the ADD consumer price, while the shadow price decreased by €22.32 (data not shown), compensating for about a quarter of the consumer price increase.

4. Discussion

The principles behind the healthy OPUS NND have proved to be of great potential advantage to the environment and associated socioeconomic cost both in previous studies [6, 7] and in the present study, which was based on Danish consumers' realistic choice to consume the NND as modelled by an incentive-driven economic model. The present study showed that the reduced shadow price associated with the ADD-to-NND diet-shift covers 70% of the increased consumer price of the diet-shift.

In the present study, we have not included health advantages of the diet-shift. But since the NND was created to be a healthier diet than the ADD, it can be presumed that there will also be a socioeconomic advantage due to improved health when choosing the NND. All in all, it may be cheaper to consume the NND than the ADD seen from a societal point of view and this should be reflected in the price we pay for the ingredients of our diet. To have a direct consequence for the consumer prices, the Rio Declaration Principle 16 ("the polluter pays principle") [18] should be implemented for food consumption. Animal produce with a high environmental impact should be more expensive and vegetables and fruit with a low environmental impact should be cheaper. That would motivate more consumers to protect the environment and improve their health through their free choice of diet.

With the above in mind, it makes sense to consider further steps that make our diets even more environmentally friendly and socioeconomically beneficial. Saxe [7] found that a vegetarian version of the NND could reduce the GWP by 67% when transport associated with imports of both the ADD and the NND was taken into account and by 59% when an 84% content of organics in the NND and the actual 8% content of organics in the ADD was also taken into account. These reductions are more impressive than in the present study. One reason for this is that the ratio of meat types in the NND study based on NND recipes by Saxe [7] was more advantageous. The recipes took into account that the production of beef in particular [19] and pork are more harmful to the environment than the production of grass-fed lamb, poultry or fish. Relative to the distribution of meat types in the ADD, the NND in Ref. [7] included only 30% beef and veal, 36% pork, and 73% chicken, but 680% grass-fed lamb and 820% venison. In the present study, the meat content relative to the ADD was 68% beef and veal, 57% pork, 39% chicken and 98% lamb. Though the overall meat reduction in the present study was 39% vs. a 35% meat reduction in the study by Saxe [7], the smaller reduction in beef and pork resulted in a smaller reduction in environmental impact in the present "real life" version of the NND. Another contributing factor to a lower effect of the NND on environment was that import distances were not included in the present study.

The NND studies [6, 7] and the present study have shown that the diet composition, the meat quantum and meat type ratio, the transport distance of imported commodities and the inclusion of organics all affect the environmental impact of what we eat and drink. So we asked ourselves if there could be other factors which may affect a diet's environmental impact. The modeled substitution of soft drinks with a designer drink in the SW-ADD proved that in theory; manipulating with the sensory quality of what we eat and drink can affect our sense of satiety and thus make us eat less. Eating less effectively saves the unnecessary expenses of consumer and environmental

impact of society and citizens and thereby reduces the shadow price of diets. Since two billion people worldwide are overweight or obese, a sensory improvement of our diets would not only increase the palatability, but also improve our health by "manipulating" consumers to eat less.

There are indications that a high-protein diets are more satisfying, e.g. Ref. [20], which may also be a way to decrease our intake, and thereby improve the general health and the environmental impact of diets.

The prerequisites for trusting in the calculated reduced shadow price associated with the ADD-to-NND diet-shift are: (1) The Ecoinvent and the LCA food data are adequate for the purpose; (2) The stepwise method calculates the environmental impacts correctly and monetizes these impacts correctly. In this study, we assume both prerequisites to be fulfilled. However, it should be mentioned that there are significant variations in findings regarding the economic value of some of the environmental benefits across studies, where some studies come out with lower shadow prices than those used in the present study.

5. Conclusions

Both of the objectives of this study were answered:

(1) This study confirms that the OPUS NND is a surprisingly efficient instrument in environmental protection—even when modeled in a "real-life" scenario based on expected consumer preferences; an instrument that can be further tuned and refined.

(2) The increased consumer cost (€284/capita/year) associated with an ADD-to-NND diet-shift is only partly (70%) countered by the reduction in environmental costs (€151/capita/year) associated with the diet-shift. Therefore, only if the health benefits of the ADD-to-NND diet-shift in future studies prove to be at least half of the environmental benefits, will it be a socioeconomic advantage to society if consumers prefer the NND over the ADD.

The potential savings associated with the reduced environmental impact of consuming the NND rather than the ADD is significant in "real life terms", as it counters the environmental impact of driving a modern passenger car for three months.

The fact that the shadow price of a diet's meat ingredients in contrast to the shadow price of all other ingredients, was found to be higher than the consumer price. Supporting a regulation of meat prices would therefore be of singular importance for politicians and legislators when focusing on future environmental regulation. The consumer should pay for the environmental (and health) impacts inflicted through their diet choices—no more, no less. That is the way of regulating the prices of automobiles, heat and power in Denmark. So why not apply the same instrument to food?

Though reducing the meat content in a diet seems to be the most efficient way to reduce the environmental impact of eating and drinking, there are obvious alternatives. One is to substitute a proportion of red meat with white meat, even when keeping the meet content constant. Another alternative is to eat less, either induced by our own free will and purpose (e.g., to "get in shape") or by seducing us to eat less through a higher protein content in our diet, or because of a higher sensory satisfaction, e.g., via an increased content of umami in your diet. Other alternatives include buying more local and less imported produce, and overall buying less organics (or even better, selecting only environmentally friendly organics). The latter statement is based on comparing the monetized environmental impact of a range of organic vs. conventional products in a previous study of the NND. Using kg as the functional unit, most organic produce has a higher overall environmental impact than their conventional counterpart.

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References

[1] Vermeulen, S. J., Campbell, B. M., and Ingram, J. S. I. 2012. "Climate Change and Food Systems." *Annu. Rev. Environ. Resour.* 37: 195-222.

[2] Nielsen, O. K., Winther, M., Mikkelsen, M. H., Gyldenkærne, S., Lyck, E., Plejdrup, M., Hoffmann, L., Thomsen, M., Hjelgaard, K., and Fause, P. 2010. *Projection of Greenhouse Gas Emissions 2009-2030.* NERI technical report no. 793.

[3] Steptoe, A., and Pollard, T. M. 1995. "Development of a Measure of the Motives Underlying the Selection of Food: The Food Choice Questionnaire." *Appetite* 25 (3): 267-84.

[4] Audsley, E., Brander, M., Chatterton, J., Murphy-Bokern, E., Webster, C., and Williams, A. 2009. *How Low Can We Go?—An Assessment of Greenhouse Gas Emissions from the UK Food System and the Scope for Reducing Them by 2050.* UK WWF study report.

[5] Tukker, A., Goldbohm, R. A., De Koning, A., Verheijden, M., Kleijn, R., Wolf, O., Pérez-Domínguez, I., and Rueda-Cantuche, J. M. 2011. "Environmental Impacts of Changes to Healthier Diets in Europe." *Ecol. Econ.* 70 (10): 1776-88.

[6] Saxe, H., Larsen, T. M., and Mogensen, L. 2013. "The Global Warming Potential of Two Healthy Nordic Diets Compared with the Average Danish Diet." *Climatic Change* 116 (2): 249-62.

[7] Saxe, H. 2014. "The New Nordic Diet Is an Effective Tool in Environmental Protection: It Reducing the Associated Socioeconomic Cost of Diets." *Am. J. Clin. Nut.* 99 (5): 1117-25.

[8] Weidema, B. P., Wesnæs, M., Hermansen, J., Kristensen, T., and Halberg, N. 2008. *Environmental Improvement Potentials of Meat and Dairy Products.* JRC Scientific and Technical report.

[9] Mithril, C., Dragsted, L. O., Meyer, C., Blauert, E., Holt, M. K., and Astrup, A. 2012. "Guidelines for the New Nordic Diet." *Public Health Nutr.* 15 (10): 1941-7.

[10] Poulsen, S. K., Due, A., Jordy, A. B., Kiens, B., Stark, K. D., Stender, S., Holst, C., Astrup, A., and Larsen, T. M. 2014. "Health Effect of the New Nordic Diet in Adults with Increased Waist Circumference: A 6-Month Randomized Controlled Trial." *Am. J. Clin. Nutr.* 99 (1): 35-45.

[11] Statistics Denmark. 2013. Accessed September 2014. Statistikbanken. www.statistikbanken.dk.

[12] United Nations (UN). 2014. "Classification of Individual Consumption According to Purpose (COICOP)." Accessed September, 2014. http://unstats.un.org/UNSD/cr/registry/regcst.asp?Cl=5&Lg=1.

[13] Earles, J. M., and Halog, A. 2011. "Consequential Life Cycle Assessment: A Review." *Int. J. Life Cycle Assess* 16: 445-53.

[14] Weidema, B. P. 2009. "Using the Budget Constraint to Monetarise Impact Assessment Results." *Ecol. Econ.* 68 (6): 1591-8.

[15] Ecoinvent. 2014. Life Cycle Inventory database version 2.1 and 3.0. Data extracted during 2013 and 2014 using the Stepwise 1.03 method in SimaPro 7.3 and 8.01. Accessed September 2014. http://www.ecoinvent.ch.

[16] LCA food database. 2004. Extracted using the Stepwise 1.03 method in SimaPro 7.3 and 8.01. Accessed September 2014. http://www.pre-sustainability.com/simapro.

[17] ISO Standard 14040. 2006. Accessed April 11, 2014. http://www.iso.org/iso/catalogue_detail.htm?csnummber=37456.

[18] United Nations (UN). 1992. "Rio Declaration on Environment and Development: Principle 16." UN Documents. Accessed March 2014. http://www.un-documents.net/rio-dec.htm.

[19] Cederberg, C., Persson, U. M., Neovius, K., Molander, S., and Clift, R. 2011. "Including Carbon Emissions from Deforestation in the Carbon Footprint of Brazilian Beef." *Environ. Sci. Technol.* 45: 1773-9.

[20] Padon-Jones, D., Westman, E., Mattes, R. D., Wolfe, R. R., Astrup, A., and Westerterp-Plantenga, M. 2008. "Protein, Weight Management and Satiety." *Am. Clin. Nutr*. 87 (5): 1558-61.